Transfer Switch Operation and Application

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Participants are encouraged to refer to the entire text of all referenced documents. In addition, when in doubt, reach out to the Authority Having Jurisdiction.
Course Objectives

Transfer Switch Operation and Application
Transfer switch equipment is available in a variety of types, with a wide array of features. Selecting the appropriate transfer switch for a specific application requires a clear understanding of site needs and application restraints.

After completing this course, participants will be able to:

- Discuss the basic operation of transfer switches and transition types to aid in the selection of equipment
- Describe the operation modes of bypass switches and isolation methods.
- Identify when it is appropriate to use a 4 pole switch as compared to 3 pole switch
What does a transfer switch do?
Transfer Switch Functionality

Load transfer between power sources
- ATS control monitors quality of both sources
  - Voltage, Frequency, Phase Rotation, Phase Loss

Load shed
- 3 Position ATS is recommended for load shedding
- Emergency systems [NEC 2017 700.4 (B)] may require load shed functionality

Load sequencing
- Multiple ATS with different time delays: e.g. motor loads
Transfer Switch Functionality

Source Transfer

Load transfer between power sources
- ATS control monitors quality of both sources
  - Voltage, Frequency, Phase Rotation, Phase Loss

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Application Types

Utility to Generator
For facilities with a standby power system and a single utility feed
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Utility to Utility
For use in facilities with redundant feeds but no standby generator
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Generator to Generator
For facilities with a prime power system using multiple on-site generators
Application Types

- **Utility to Generator**: For facilities with a standby power system and a single utility feed.

- **Utility to Utility**: For use in facilities with redundant feeds but no standby generator.

- **Generator to Generator**: For facilities with a prime power system using multiple on-site generators.

- **Three-Source System**: Two generator sets backup a utility service.
Transition Types

- Open Transition (In Phase)
- Open Transition (Time Delayed / Programmed Transfer)
- Closed Transition
Open Transition

In Phase Transfer

- Break-before-make switching action
- Power interruption of 3-5 Cycles (50-80 ms)
- Suitable for resistive and small motor loads (<20hp)
Open Transition

In Phase Transfer
Open Transition
Retransfer (In Phase)
In Phase Transition

Inductive Loads

Utility/Generator Set Voltage in Sync

Load (Residual) Voltage

Switch Closes to Utility
Open Transition

Time Delayed

Utility/Generator Set Voltage in Sync

Load (Residual) Voltage

Switch Closes to Utility
Open Transition

Time Delayed

Load Voltage

Programmed delay
Time Delayed Transition

Residual Voltage Decay

- Voltage decays exponentially (independent of motor speed)
- NEMA MG-1 recommends a delay of 1.5 Motor Open Circuit Time Constants
  - Voltage will be at 22% of nominal
- For multiple motors, use the time delay for the largest motor

Spec Note Open transition and delayed transition switches shall be supplied with a 3 position mechanism. The switch control will move to the center off position when there is a load shed signal from Generator set controller or a supervisory controller. The switch will also move to the center off position during delayed transition for a pre programmed amount of time, and aid in residual voltage dissipation

Residual Voltage Decrement

Source: IEEE Orange Book
Closed Transition

- Make-before-break - uninterrupted power transfer when both sources are available
- Seamless transfer of the load by momentarily paralleling both sources (<100 milliseconds)
Closed Transition

Retransfer

Reference Cummins PowerHour “Guidelines for ATS selection: How to choose the right transfer solution for your power application.” for more details!
Synchronizing

- Synchronization is the mechanism of matching frequency, phase and voltage of AC power sources
  - Phase and Frequency: engine governor fuel
  - Voltage: alternator field excitation

Reference Cummins PowerHour “Features of Generator Set Control Based Paralleling” for more details!
Closed Transition

Synchronizing Methods

- Passive synchronizing - sync check
  - Wait for sources to drift into permissive window

- Sync by slip frequency
  - Drive sources through permissive window

- Active sync
  - Relies on generator set control to match utility waveform
Synchronization Methods

Passive Synchronization (Sync Check)

- Wait for sources to drift into sync
  - Does not drive sources to come into phase
- Depends on sources running at slightly different frequency
  - Sources with same frequency will not drift into sync
  - If frequency is too different, permissive window might be too short

![Diagram of Permissive Window](image-url)
Synchronization Methods

Sync by Slip

- Generator set frequency is set to a slightly different value compared to utility frequency
- Drive sources through permissive window
Synchronization Methods

Active Sync

- Actively adjust generator set governor and voltage regulator control loops to match the utility waveform
  - Transfer switch sends “sync” command to generator controller
  - Generator set control adjusts fueling and excitation

Spec Note: The transfer switch controller shall be capable of providing a synchronization signal to the generator set controller when both sources are available during a transfer. This signal shall drive active voltage, frequency and phase matching to enable fast synchronization between sources, hold synchronization during the transfer process so transient current spikes are minimized.

Closed Transition

Risks

- Why do breakers trip during closed transition transfer?
  - Current flows between sources caused by a difference in instantaneous voltage between sources at the instant of closure
Closed Transition

Risks

- Why do breakers trip during closed transition transfer?
  - Current flows between sources caused by a difference in instantaneous voltage between sources at the instant of closure

- What causes the difference in voltage?
  - Phase angle difference between sources
    - Use active synchronizing
  - Difference in RMS voltage between sources
    - Use synchronizer with voltage match
  - Transient condition on one of the sources
    - Allow only one switch to transfer at a time
Closed Transition

Preventing Extended Paralleling

- Shunt trip breaker on normal or emergency source in the event of a failure of ATS to disconnect
  - Use Fail to disconnect signal from ATS control or
  - Use External parallel timer and lockout relay

- Function is required by many utilities
Concept Check

Which transition types are not suitable for stored energy loads (large motors, MRIs)?

a) Open (In Phase)
b) Open (Delayed)
c) Closed
d) Both b) and c)
Concept Check

Which transition types are not suitable for stored energy loads (large motors, MRIs)?

a) Open (In Phase)
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d) Both b) and c)
Open Transition

Time Delayed

Utility/Generator Set Voltage in Sync

Load (Residual) Voltage

Switch Closes to Utility
Short Circuit Ratings

- UL 1008 defines test requirements for short circuit ratings

- Withstand and Close-On Rating (WCR)
  - Ability to withstand and close into a fault current (kA) until a protective device opens
  - Test sequence is as follows:
    - Specified fault current is applied for either
      - A specified period of time (e.g. 50 ms)
      - Until the specified overcurrent protective device clears the fault
      - After withstanding the fault current, the ATS must close into the fault using the same set of contacts

- Short Time Rating
  - Ability to carry rated current after a short circuit event
Bypass Transfer Switch

- Allows service of ATS without disrupting power to critical loads
- By having two transfer switches, the bypass transfer switch adds redundancy to the system
- **Bypass Isolation**: Bypass first and Isolate later (no power interruption to load)
- Watch out for term “Isolation Bypass”
Bypass Transfer Switch

Sequence of Operation – Normal Mode

- Normal power flow through ATS
- Sequence of operation of ATS is unchanged
- Normal power does not flow through bypass transfer switch
Bypass Transfer Switch

Sequence of Operation – Test Mode

- Bypass is connected to the same source as the ATS
- Dead source interlock
- Bypass to same source does not cause power interruption
Bypass Transfer Switch

Sequence of Operation – Isolation Mode

- With bypass closed, ATS can be opened, and drawn out for service
- ATS control is still active and sends a generator set start command upon normal power failure
- Loads can be manually transferred to alternate source using the bypass switch
Normal Test Isolation

- Normal automatic operation
- Bypass is open

- Bypass closed and carries load
- Manual transfer. No power across ATS
- ATS retains sensing and operating functionality

- Bypass closed and carries load
- Manual transfer
- ATS removed for service or replacement

Spec Note: Provide bypass isolation type switch. The transfer switch shall be capable of bypassing the power flow between two live sources before isolation of the automatic mechanism. This first bypass then isolation mechanism shall not result power interruption under normal sequence of operation or when maintenance on the automatic mechanism is required.
Concept Check

In test position, a bypass transfer switch has the following property:

a) ATS is completely isolated from the bypass mechanism
b) ATS retains sensing of sources
c) It cannot start the genset
d) ATS can be removed for service/replacement
Concept Check

In test position, a bypass transfer switch has the following property:

a) ATS is completely isolated from the bypass mechanism

b) ATS retains sensing of sources

c) It cannot start the genset

d) ATS can be removed for service/replacement
**Bypass Positions**

### Normal

- Normal automatic operation
- Bypass is open

### Test

- Bypass closed and carries load
- Manual transfer. No power across ATS
- ATS retains sensing and operating functionality
- Functional testing without load interruption

### Isolation

- Bypass closed and carries load
- Manual transfer
- ATS removed for service or replacement

**Spec Note** Provide bypass isolation type switch. The transfer switch shall be capable of bypassing the power flow between two live sources before isolation of the automatic mechanism. This first bypass then isolation mechanism shall not result in power interruption under normal sequence of operation or when maintenance on the automatic mechanism is required.
Transfer Switch Selection

3 Pole vs 4 Pole

Use a 4 pole transfer switch when ground fault sensing is required

- Most common method is to use GF protection in breaker at the service disconnect
- Two rules for proper GF sensing
  - There must be only one neutral/ground bond on any neutral bus at one time
  - Ground fault sensors must be downstream from the bond

These two rules drive the requirement that 4 pole transfer switches must be used when ground fault sensing is required or may be required in the future.

IEEE Std 446-1995 (Orange Book)
7.9.1 "for most emergency and standby power systems with ground-fault systems, switching of the grounded circuit conductor by the transfer switch is the recommended practice."
Course Summary

Transfer Switch Operation and Application

- Transfer switches
  - Provides means of transferring loads between two power sources
  - Allows shedding of non-critical loads. Requires a 3 position switch.
  - Allows stepping of loads onto a single generator set.

- Transition types
  - Delayed / Programmed Transition should be used for motor loads. Requires a 3 position switch.
  - Closed transition transfer switches offer transition without power interruption but introduces risks and costs

- Bypass transfer switch allows service of ATS without disrupting power to critical loads. Specify Bypass Isolation switch.
- 4 Pole transfer switches should be used when ground fault sensing is required

Specify:

- 3 position mechanism that is required for load shed and delayed transitions.
- Bypass isolation mechanism for uninterrupted power transfer.
- 4 pole transfer switch for effective ground fault sensing

Avoid specifying:

- Brand-specific components that can limit design options and increase cost
Additional Resources

Cummins White Papers:
- Transfer switch set up for reliability and efficiency, part 1, 2 & 3
- Considerations for reliable closed transition switches
- Bypass transfer switch mechanisms

Cummins On-Demand Webinars:
- Functions and Features of Generator Set Control Based Paralleling

Future Power hours:
- Withstand and close on ratings for Transfer switches - November 2019
Q&A

Type your questions, comments, feedback in the WebEx Q&A box. We will get to as many questions as we can.

We will publish consolidated FAQ along with presentation and webinar recording on powersuite.cummins.com

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Please contact Mohammed Gulam if you have any questions related to the PowerHour webinar (mohammed.gulam@cummins.com)